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**Evaluation of Volatile Organic Compound Emissions
from Line-X XS-350 Polymer Coating**

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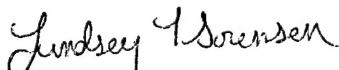
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Evaluation of Volatile Organic Compound Emissions from Line-X XS-350 Polymer Coating

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Introduction

The use of Line-X XS-350 polymer as an interior retrofit coating for occupied building structures to improve their blast resistance, has raised a major concern by potential users of the polymer retrofit technology. That concern is if any volatile organic emissions off-gas from the curing polymer and if so are they within permissible exposure limits. This study addresses those concerns by conducting the pertinent tests and/or analyses to document the emissions and potential health and safety aspects of Line-X XS-350.

Methodology

Samples of Line-X XS-350 polymer (approximately 350 ± 20 grams) were sprayed on 12 X 12-inch aluminum plates on day one, and held in room air at room temperature (70°F) for the length of the experiment. Emission evaluations were made at 0-24 hrs, 24-48 hrs, 48-72 hrs, one week (70°F and 95°F) and one month (70°F and 95°F). Each Line-X XS-350 polymer surface coated plate was placed inside an evacuable, Teflon® coated chamber with an internal volume of 188 liters. Samples of the emitted gases were withdrawn through a side port into a 1/8-in Teflon® transfer line routed to a cryogenic sample loop. A vacuum pump/electronic flow controller system maintained a 25 ml / min flow of sample through the cryogenic sample loop. In all cases 100-ml samples were collected. The collection sample loop (1.3 ml-silanized, glass bead filled-trap) was maintained at -65°C and flash heated to 300°C for injection into the gas chromatograph (GC) via a heated rotary valve. Compound separation was achieved using a Restek Rtx-1 column (30m, 0.53mm id., 1.0um film thickness) in a Hewlett-Packard (HP) 5980 II GC equipped with a HP 5972 mass selective detector (MSD). Helium (UHP, Air Products) was used as the carrier gas. The oven program was a temperature ramp starting at 35°C (hold 5 min.) to 250°C at a rate of 8°C per min. The MSD scanned the effluent from 33 to 350 m/z at a rate of 1.9 scans per second.

The emission profile of the coating was monitored over a 24-hour period, with samples taken every hour (approx.) except over night. The emission time profile of the emitted individual chemicals was determined and used to calculate the individual chemical emission rate.

Mass spectra of the individual emitted chemicals were identified using Wiley Mass Spectral Library comparisons. Quantitation was performed by peak area count comparisons with standard curves prepared from pure known compounds using the described sampling methodology.

Results

The individual compounds identified from emissions of the Line-X XS-350 polymer coated aluminum plates are listed in Table 1.

Table 1.

Compound(s):
Toluene
Perchloroethene (PCE)
Chlorobenzene
Ethylbenzene
o-Xylene
Decane
Undecane
Triethyl phosphate (TEP)

The emission profiles of the various compounds at room temperature (70°F) are tabulated in Table 2. These results are shown as a function of time from initial application of the Line-X XS-350 polymer to a 1 square foot aluminum plate and are expressed in terms of grams of the compound per minute per square foot of sprayed Line-X XS-350 polymer. Figures 1a, 1b and 1c show a graphical representation of the emission rates.

Table 2.
Rate of Emissions at Room Temperature (70°F)
($\text{g min}^{-1} \text{sq. ft}^{-1}$)

Compound:	MDR	24hrs	48 hrs	72 hrs	1 wk	1 mo
Toluene	3.44×10^{-9}	2.09×10^{-7}	1.07×10^{-7}	7.90×10^{-8}	9.25×10^{-9}	$8.91 \times 10^{-10}^*$
Perchloroethene (PCE)	4.69×10^{-9}	1.53×10^{-7}	2.61×10^{-8}	1.39×10^{-8}	1.70×10^{-8}	ND
Chlorobenzene	4.25×10^{-9}	3.94×10^{-8}	1.83×10^{-8}	1.47×10^{-8}	ND	ND
Ethylbenzene	5.32×10^{-9}	3.92×10^{-8}	1.20×10^{-8}	1.87×10^{-8}	ND	ND
o-Xylene	2.76×10^{-9}	3.55×10^{-8}	1.35×10^{-8}	1.20×10^{-8}	ND	ND
Decane	7.60×10^{-9}	8.61×10^{-8}	5.47×10^{-8}	4.66×10^{-8}	2.68×10^{-8}	$1.95 \times 10^{-8}^*$
Undecane	7.60×10^{-9}	4.04×10^{-8}	2.83×10^{-8}	2.90×10^{-8}	ND	ND
Triethyl phosphate (TEP)	4.00×10^{-7}	2.12×10^{-4}	2.51×10^{-4}	4.77×10^{-6}	ND	ND

MDR= Minimum Determinable Rate

ND= Not Detected, value is below the MDR using our analytical technique.

* 48 hour experimental duration

Fig. 1a

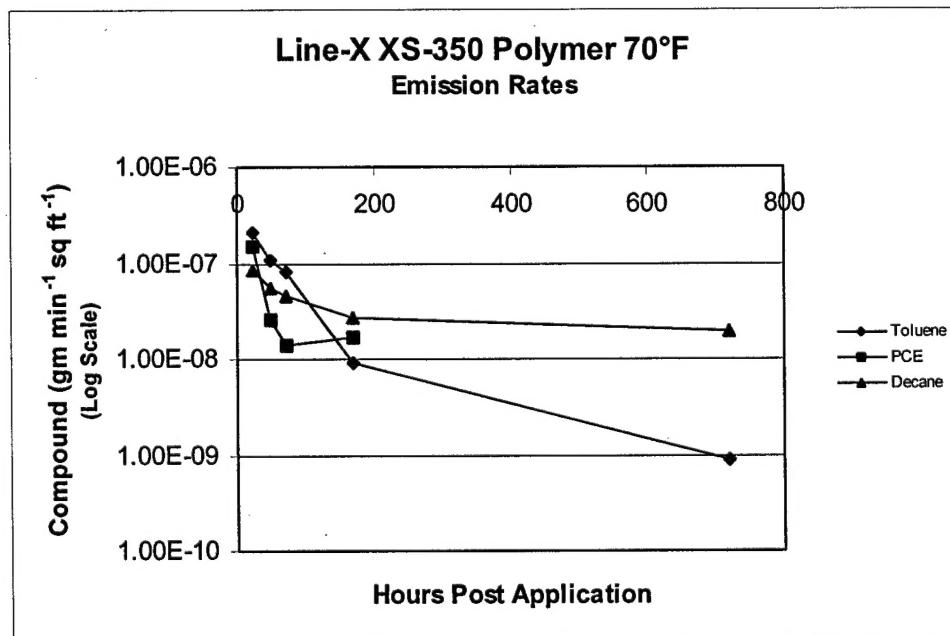


Fig. 1b

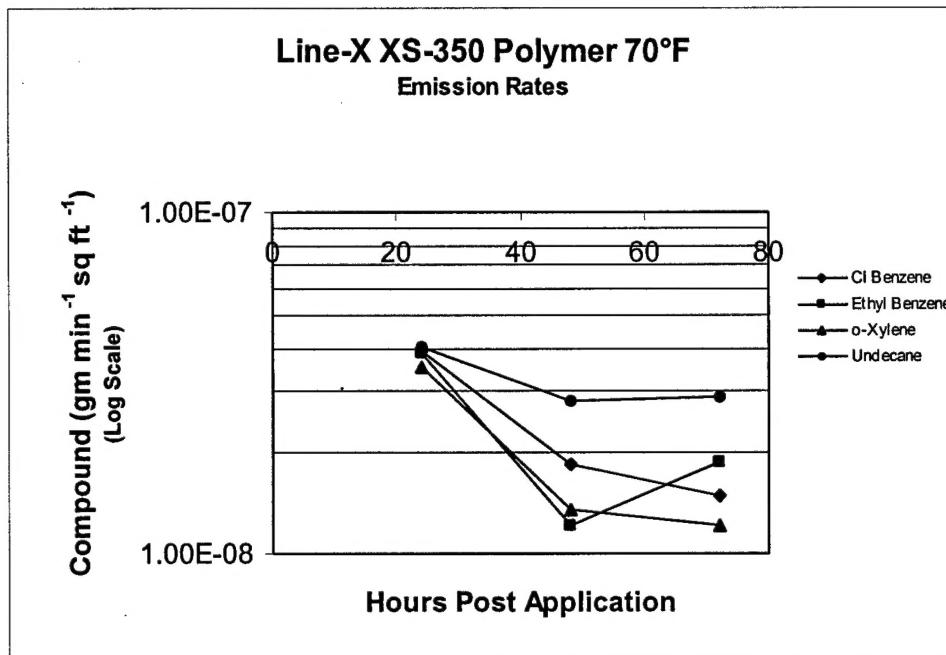
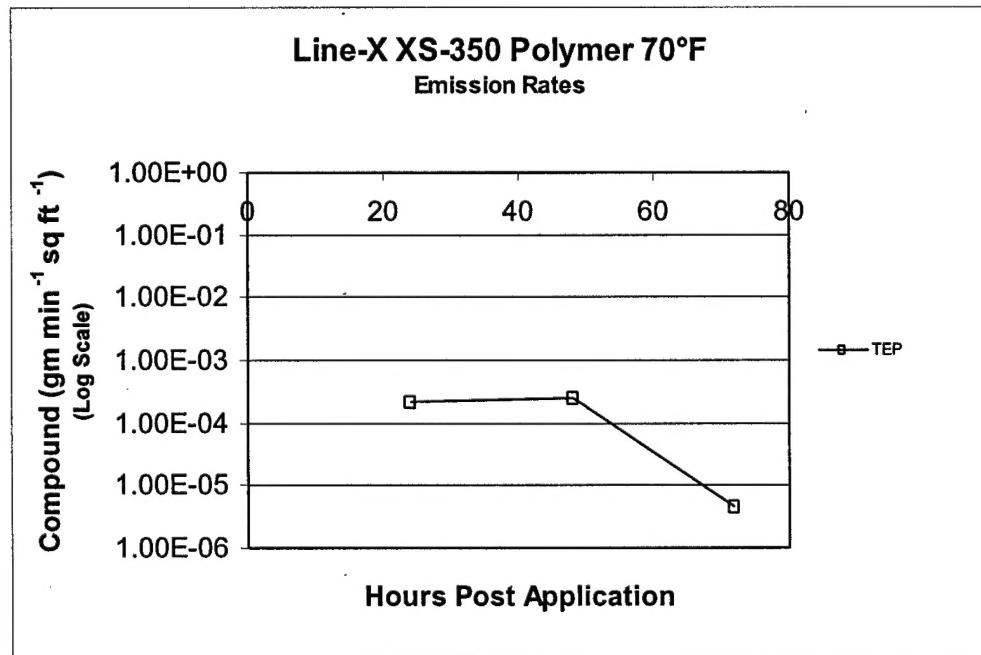


Fig. 1c



In addition to the room temperature study, a 95°F study was performed to simulate a warm climate or loss of climate control. The results are presented in Table 3, and Figures 2a, 2b, and 2c.

Table 3.
Rate of Emissions at Elevated Temperature (95°F)
($\text{g min}^{-1} \text{ sq. ft}^{-1}$)

Compound:	2 weeks	1 month
Toluene	7.09×10^{-8}	4.08×10^{-8}
Perchloroethene (PCE)	4.83×10^{-8}	3.38×10^{-8}
Chlorobenzene	2.36×10^{-8}	1.29×10^{-8}
Ethylbenzene	2.74×10^{-8}	1.04×10^{-8}
o-Xylene	1.56×10^{-8}	6.45×10^{-9}
Decane	7.06×10^{-8}	4.06×10^{-8}
Undecane	6.42×10^{-8}	3.05×10^{-8}
Triethyl phosphate (TEP)	2.18×10^{-5}	1.35×10^{-5}

Fig. 2a

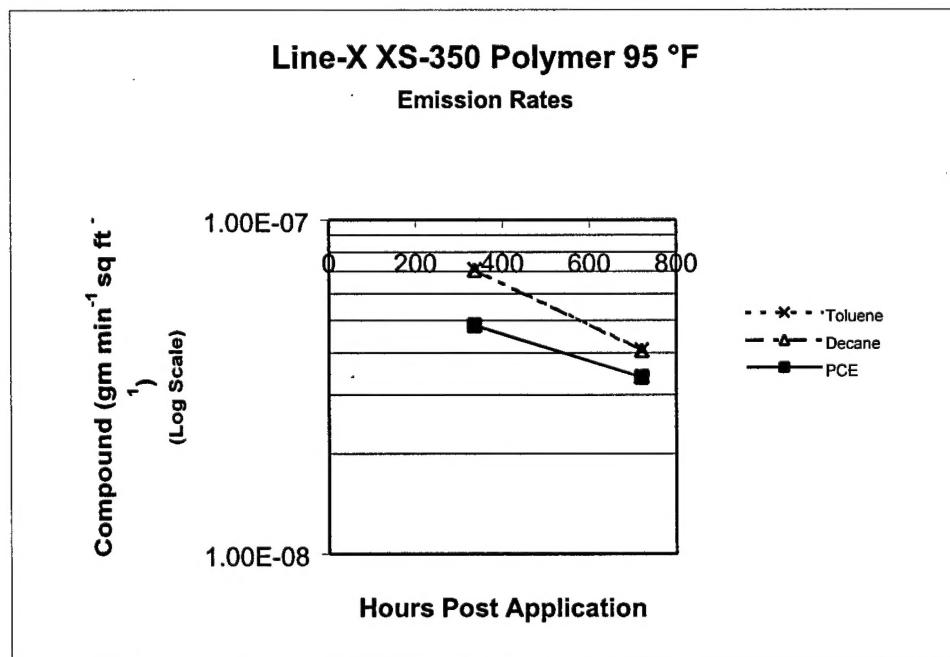


Fig. 2b

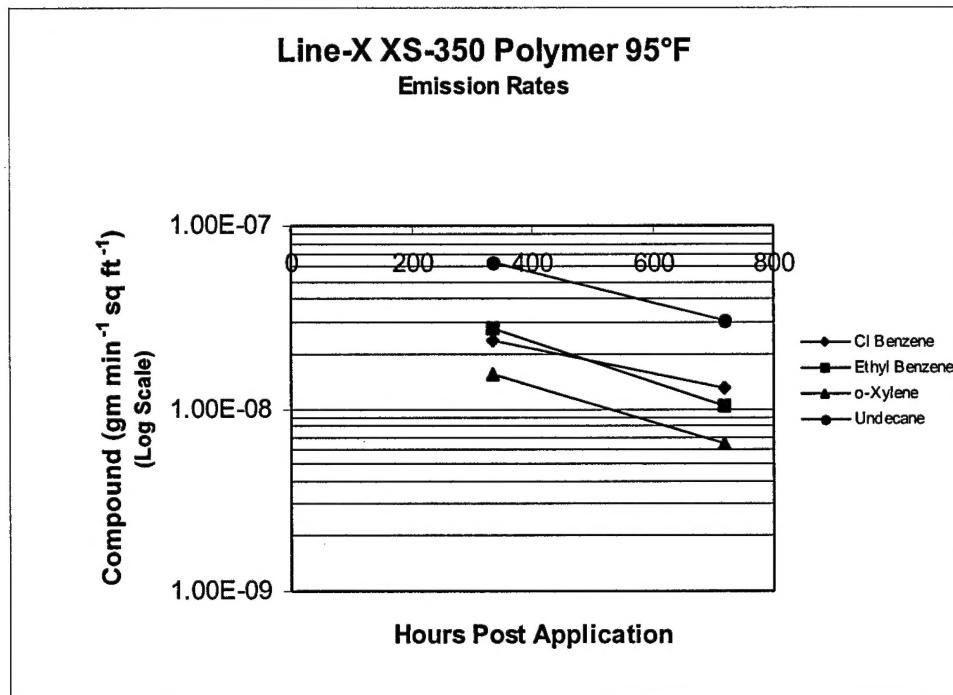
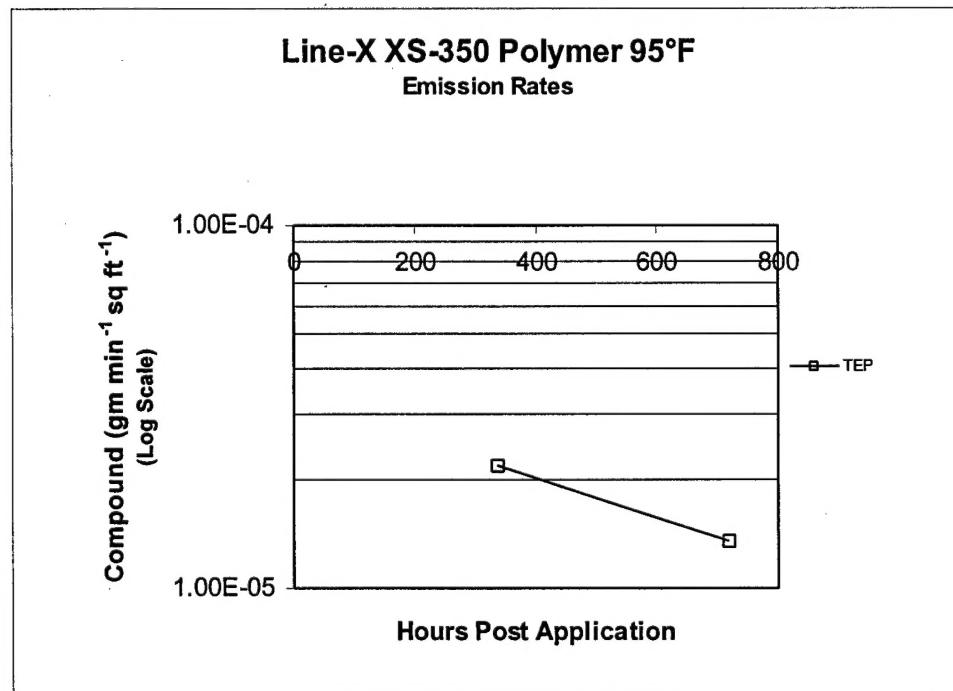


Fig. 2c



Discussion

The rate of emission for each compound identified from the Line-X XS-350 polymer decreases as a function of time. At a temperature of 70°F, emissions of chlorobenzene, ethylbenzene, o-xylene, undecane and triethyl phosphate became undetectable after the third day post application of the coating. Perchloroethene was undetectable after one week. Toluene and decane were still detectable at one month, although at very low emission rates. At the elevated temperature of 95°F, emissions of all identified compounds were detectable at two weeks and at one month post application at decreasing emission rates. The study did not proceed past one month.

Conclusions

Most of the compound's emissions were undetectable after one-week post application with toluene and decane emissions significantly decreased after one month. With adequate ventilation after application of the Line-X XS-350 polymer, the levels of emitted compounds will be below National Institute for Occupational Safety and Health (NIOSH) Time weighted Averages (TWA) for continuous 10-hour exposures after one-day post application.¹

Example:

Perchloroethene TWA = 25PPM (170mg/m³)

Emission rate day 1: 1.53×10^{-7} g min⁻¹ sq. ft⁻¹

Assume a structure with the interior dimensions 40ft x 20ft x 8ft high. The wall surface area is 960sq ft. and the volume is 181.23m³.

$$1.53 \times 10^{-7} \text{ g min}^{-1} \text{ sq. ft}^{-1} \times 960 \text{ sq ft} = 1.46 \times 10^{-4} \text{ g min}^{-1}$$

$$1.46 \times 10^{-4} \text{ g min}^{-1} \times 60 \text{ min} \times 24 \text{ hrs} \times 1000 \text{ mg/g} = 211.51 \text{ mg/24 hrs}$$

$$211.51 \text{ mg} / 181.23 \text{ m}^3 = 1.17 \text{ mg/m}^3$$

The predicted concentration is well below the NIOSH TWA for perchloroethene after one day.

TWA's for NIOSH Recommended Exposure Limits (REL's) and OSHA Permissible Exposure Limits (PEL's) are summarized in Table 4. Also listed in Table 4 are the hypothetical concentrations of each compound that accumulate in a structure after the first 24 hours post-application of Line-X XS-350. Concentrations were calculated assuming a structure with interior dimensions of 40ft x 20ft x 8ft high and no air exchange. This is a worst-case situation for a structure of this size.

Table 4. Summary of Available Health & Safety Information

Compound	NIOSH REL's	OSHA PEL's	Line-X XS-350
	TWA (10 Hours) mg/m ³	TWA (8 Hours) mg/m ³	After 24 hours mg/m ³
Toluene	377 (100ppm)	754 (200ppm)	1.59 (0.42ppm)
Perchloroethene (PCE)	170 (25ppm)	678 (100ppm)	1.17 (0.17ppm)
Chlorobenzene	Not Established	346 (75ppm)	0.30 (0.065ppm)
Ethylbenzene	434 (100ppm)	434 (100ppm)	0.30 (0.069ppm)
o-Xylene	434 (100ppm)	434 (100ppm)	0.27 (0.062ppm)
Decane	2034 (350ppm)	2905 (500ppm)	0.66 (0.113ppm)
Undecane	2237 (350ppm)	3195 (500ppm)	0.31 (0.048ppm)
Triethyl phosphate (TEP)	Not established*	Not Established*	1617 (217ppm)

* Although neither NIOSH nor OSHA have established exposure levels, MSDS's for TEP CAS No. 78-40-0 state that TEP causes eye irritation and is a cholinesterase inhibitor and may cause nerve damage similar to other phosphate esters.

References

¹ NIOSH Pocket Guide To CHEMICAL HAZARDS, U.S. Department of Health And Human Services, June 1997